PIV Measurements of Atmospheric Turbulence and Pollen Dispersal Above a Corn Canopy

BIOCOMPLEXITY

Instrumentation to measure the emission and transport of biological aerosols in the atmosphere: Linking across scales from microns to kilometers

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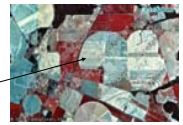
Abstract

Dispersal of pollen grains by wind and gravity (Anemophilous) is one of the oldest means of plant fertilization available in nature. Recently, the growth of genetically modified foods has raised questions on the range of pollen dispersal in order to limit cross-fertilization between organically grown and transgenic crops. The distance that a pollen grain can travel once released from the anther is determined, among others, by the aerodynamic parameters of the pollen and the characteristics of turbulence in the atmosphere in which it is released. Turbulence characteristics of the flow above a pollinating corn field were measured using Particle Image Velocimetry (PIV). The measurements were performed on the eastern shore of the Chesapeake Bay, in Maryland, during July 2003. Two PIV systems were used simultaneously, each with an overall sample area of 18x18 cm. The spacing between samples was about equal to the field of view. The PIV instrumentation, including CCD cameras, power supply and laser sheets forming optics were mounted on a measurement platform, consisting of a hydraulic telescopic arm that could be extended up to 10m. The whole system could be rotated in order to align it with the flow. The flow was seeded with smoke generated about 30m upstream of the sample areas. Measurements were carried out at several elevations, from just below canopy height up to 1m above canopy. The local meteorological conditions around the test site were monitored by other sensors including sonic anemometers, Rotorod pollen counters and temperature sensors. Each processed PIV image provides an instantaneous velocity distribution containing 64x64 vectors with a vector spacing of ~3mm. The pollen grains (~100mm) can be clearly distinguished from the smoke particles (~1mm) based on their size difference. The acquired PIV data enables calculation of the mean flow and turbulence characteristics including Reynolds stresses, spectra, turbulent kinetic energy and dissipation rate. Data analysis is currently in progress.

Fieldtrip July 2003

Hurlock MD, Eastern shore of Chesapeake bay

- 150 acres half circle corn field. Other half potatoes.
  - – Advantage: huge fetch (400m).
  - – Disadvantage: only measuring at specific wind directions.
- Irrigated field.
  - – Advantage: Guaranteed pollination
  - – Disadvantage: some of the equipment needs to be moved when irrigation arm comes over.
- Easy access to field site.
- Flat terrain, obstructions far away.

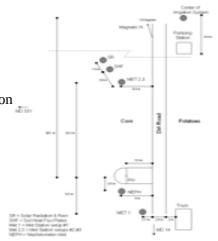


Experimental Field Setup: Large Scale Dispersion

•Particle Image Velocimetry (PIV)
W. Zhu, L. Luznik, R. van Hout, J. Katz

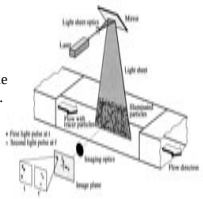
•Pollen samplers
M. Thronenburg, G. Brush

•Sonic anemometers/Meteorological station
J. Kleissl, M. Parlange



Basic description of Particle Image Velocimetry (PIV)

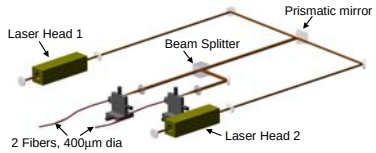
- Imaging of tracer particles in the flow at two different time instants. Knowledge of their displacement through statistical correlation results in the fluid velocity field.
- Advantage over point measurements: whole field, velocity information in spatial domain.
  - – Instantaneous spatial structure of the flow
  - – Non-intrusive measurement technique



Experimental Setup

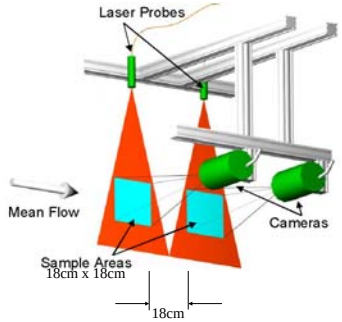
Light Source

- Dual-head Flashlamp Pumped-dye Laser
- Rhodamine 6G dye, 350mJ/pulse at 594nm, 2ms pulse length
- up to 15pulse-pairs/s with unlimited in-pair delay
- Max output: 120mJ/pulse before damage to fibers

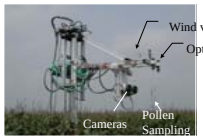


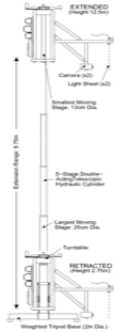
PIV Setup

- Two Dalsa SMD CCD cameras, 2kx2k, 12 bits, auto-correlation, hardware based image shift, 4 frame/second.
- Data streamed over 70m to 240GB disk arrays
- Seeding of the flow by two Rosco 1600 smoke generators.
- Hydraulic Platform: System can be lifted up to 10 meters



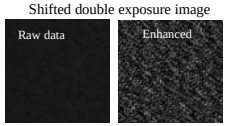
Field Experiment





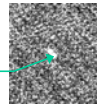
PIV data

Shifted double exposure image

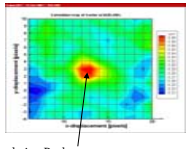


Pollen grains (~80µm)
Smoke (~1 µm)

Pollen

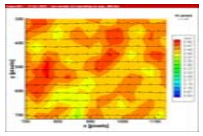


Auto correlation map of 64x64 pixels

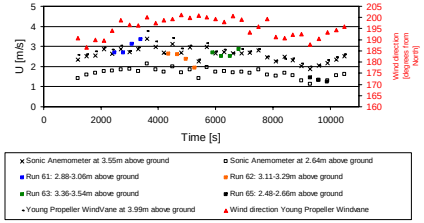


Correlation Peak location

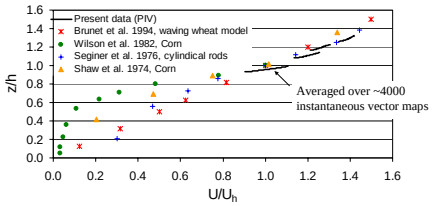
Instantaneous vector map



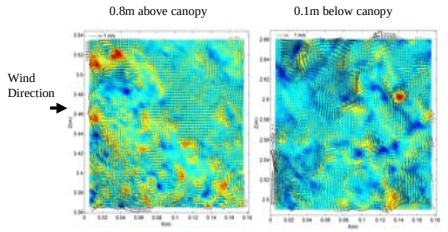
Wind data 07/23/03



Mean Velocity Profiles



Velocity Fluctuation Vectors and Vorticity Distribution



Convergence RMS u', w', and Reynolds stress u'w' (3.45 m)

Frame rate = 4Hz; N = image number